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## Thoracolumbar spinal fractures: radiological results of transpedicular fixation combined with transpedicular cancellous bone graft and posterior fusion in 183 patients

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**Abstract** In internal posterior fixation of thoracolumbar fractures combined with transpedicular cancellous bone graft and posterior fusion of the intervertebral facet joints at the level of the destroyed end plate it is still uncertain as to whether significant vertebral body collapse and loss of correction of the regional angle (RA) and the intervertebral angle (IVA) occur (after removal of the implants). These questions were investigated in a retrospective study of 183 consecutive patients, 18–65 years old, with a spinal fracture between the 9th thoracic and the 5th lumbar vertebral body (inclusive), treated operatively between 1988 and 1996 (27% had objective neurological deficit, 37% had multiple injuries). According to the Comprehensive Classification, 128 type A, 32 type B and 21 type C fractures were identified preoperatively. Changes in the anterior wedge angle (AWA), the IVA and the RA were measured preoperatively, and within 1 month, 9 months and 24 months postoperatively. The effect of implant failure was also evaluated. The normality of the distribution was tested using the Kolmogorov-Smirnov (K-S) test. The one-sample runs test and the

*t*-test were used to evaluate angle changes. Angles in patients with and without implant failure were compared using the unpaired *t*-test. Almost complete restoration of the AWA could be achieved during operation. Postoperative changes in AWA were either very small or not significant. The reduced vertebral body did not collapse after 9 months, when most of the patients (170) underwent removal of the implants, but significant changes in IVA were found after implant removal. Correction of the RA was statistically significant before implant removal, but the RA 2 years after surgery had become almost the same as the preoperative values. Changes at the level of the intervertebral space, occurring after implant removal, contributed to the loss in the RA. Broken pedicle screws (10.9% of the patients) resulted in significant changes in the AWA and RA before implant removal, but did not influence the IVA.

**Keywords** Spinal fractures · Fracture fixation, internal · Thoracolumbar spine · Spinal fusion · Transpedicular instrumentation · Implant failure · Bone grafting

### Introduction

The rationale for the operative treatment of thoracolumbar spinal fractures has been the subject of discussion in about 300 articles between 1975 and 1994 [13]. Despite this it

remains unclear exactly what changes occur in the disturbed anatomy of the spine during surgery and during the course of treatment.

Since Aebi et al. showed that a better anatomical correction could be achieved with the Dick internal fixator

technique than with the classical Harrington rods [1, 2, 3], we have been treating patients with unstable fractures, and fractures with considerable angulation or neurological deterioration by posterior reduction and stabilization with short segment fixation with Dick's internal fixator. In those cases in which the fracture of the vertebral body was actually reduced, the posterior procedure was combined with a transpedicular autologous cancellous bone graft. Posterior fusion of the intervertebral facet joints only at the level of the destroyed end plates was performed in all cases. As all patients were treated in a strict working protocol, our work resulted in a unique database over a 10-year period. We managed to collect almost complete data during a follow-up period of 2 years for our radiological retrospective analysis.

For the study reported here, we tried exclusively to find answers to the following questions:

1. Does the vertebral body collapse after removal of the implants, despite transpedicular bone grafting?
2. Is correction of the regional angle (RA) maintained after surgery?
3. And if not, does the loss in the intervertebral angle (IVA) contribute to this change?
4. What is the influence of implant failure on the radiological measurements?

## Materials and methods

All consecutive patients, aged 18–65 years, with a fracture of the thoracolumbar spine between the 9th thoracic and the 5th lumbar vertebral body, surgically treated at the Traumatology Department of the University Hospital Groningen between March 1988 and August 1996 were included in this study, and of these 51% were referred from other hospitals. Patients with fractures in osteoporotic bone or with other pathological conditions (metastases) were excluded. All the available clinical records, and operative, follow-up, rehabilitation plus all radiographic material (including conventional tomographs and computerized tomographs with 2D reconstructions) were reviewed.

By definition all patients had sustained a trauma. Falls and jumps from a height accounted for 64.5% of all injuries, and 25.1% were from traffic accidents. Young adults were predominant; the median age was 32 years.

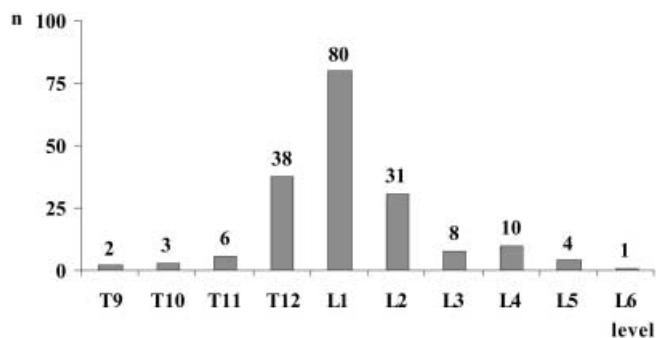


Fig. 1 Fracture level in 183 patients

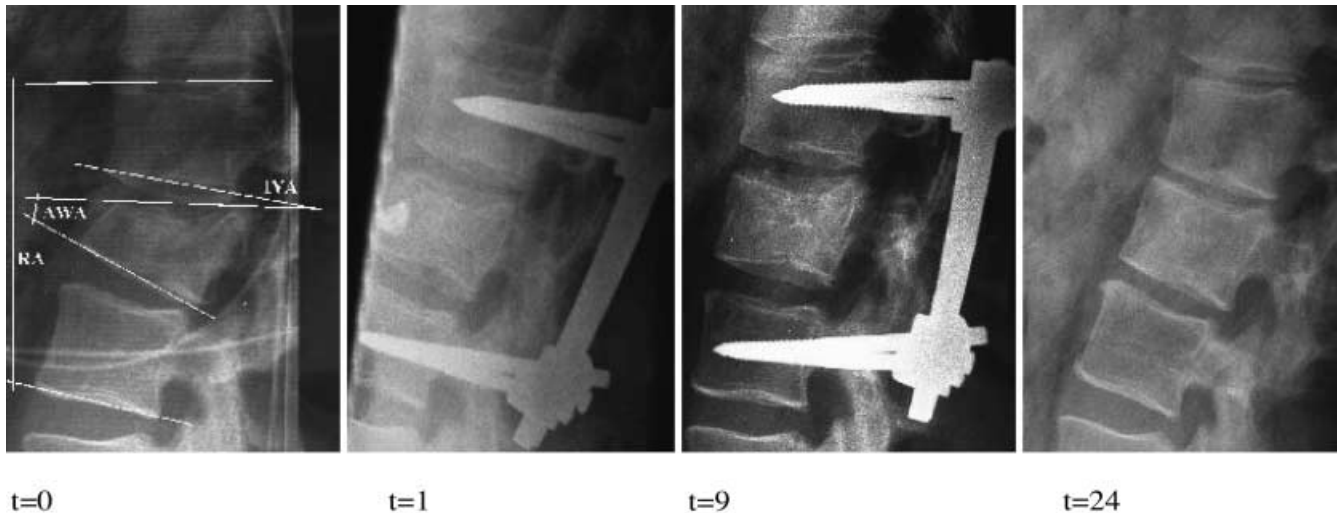
Although many of the patients showed temporary sensory loss in the legs, 27% had a definitive objective neurological deficit, varying from (partial) conus-cauda lesions to complete paraplegia, and 37% of the patients had other injuries unrelated to the spinal fracture. Most of the patients suffered a 12th thoracic, and a 1st or 2nd lumbar fracture (Fig. 1). According to the Comprehensive Classification [19], 128 were type A fractures, 32 type B and 21 type C as identified preoperatively. Two fractures could not be classified according to the Comprehensive Classification because of missing data (Table 1). An example of a type A3.1 fracture is shown in Fig. 2.

If possible, the operative treatment was performed on day 4 after trauma (median, range 0–31 days), but 17 patients were operated upon immediately after admission because of neurological impairment, and 28 after more than 10 days. During surgery, 17 out of 105 fractures thought to be type A were found to be type B lesions after exploration of the dorsal ligaments.

All fractures were treated by instrumental angular reduction, distraction and stabilization with Dick's internal fixator [10, 11, 12]. Since 1995 we have used the Universal Spine System (Synthes). The procedure was combined with unilateral (1988–1989) or bilateral (1989–1996) transpedicular cancellous bone grafts as described by Daniaux [7, 8]. Posterior spondylolysis was added only at the level of the disturbed cranial or caudal end plate. No ventral operations or laminectomy were performed. Approximately 10 days after surgery the patients were transferred to a rehabilitation centre for a mean stay of 4 weeks. Here they were allowed to mobilize in a standard thoracolumbosacral orthosis. The brace was worn for 9 months; the first 6 months day and night and the last 3 months only during the day.

Table 1 Comprehensive Classification in 183 patients

A	128	A1	20	A1.1	1
				A1.2	17
				A1.3	2
		A2	4	A2.1	1
				A2.2	0
				A2.3	3
		A3	104	A3.1	60
				A3.2	26
				A3.3	18
B	32	B1	16	B1.1	3
				B1.2	13
				B1.3	0
		B2	14	B2.1	1
				B2.2	1
				B2.3	12
		B3	2	B3.1	1
				B3.2	0
				B3.3	1
C	21	C1	15	C1.1	3
				C1.2	0
				C1.3	12
		C2	5	C2.1	5
				C2.2	0
				C2.3	0
		C3	1	C3.1	1
				C3.2	0
				C3.3	0
Unknown					2



**Fig. 2** AWA, IVA and RA in radiographs during the course of treatment of a type A3.2 fracture in a 39-year-old man (as an example) ( $t=0$  before surgery,  $t=1$  within 1 month of operation,  $t=9$  before implant removal at 9 months,  $t=24$  24 months after trauma)

After 9 months all implants were removed except in five patients in whom the spondylodesis had been performed at the same segments as the internal fixation. At 12 months all patients were instructed to recommence all their former activities. The last follow-up examination was 2 years after the initial operation. One patient died postoperatively of a severe intrathoracic bleeding complication. Three patients died during follow-up due to pulmonary complications in complete paraplegia (4, 8 and 13 months after operative treatment). Two patients performed lethal suicidal attempts during follow-up. Two patients were lost to follow-up. Since 1989 only minor changes in the treatment protocol have been made.

We limited our study to four parameters (Fig. 2):

1. Changes in the anterior wedge angle (AWA) of the fractured vertebral body in all our patients. Additionally, we performed a separate evaluation of those (101) patients with type A3 fractures with a positive AWA on admission.
2. Changes in the IVA at the end plate of the fractured vertebral body at the level of the involved disc. The "second" disc's IVA was not directly measured.
3. Changes in the RA (i.e. the angle formed by the cranial and caudal end plates of the adjacent intact vertebrae).
4. The influence of implant failure upon the changes in AWA, IVA and RA.

Angles were measured in plain radiographs preoperatively, and within 1 month postoperatively, 9 months (before removal of implants, which we did in 97% of the patients) and 24 months postoperatively (all patients). The differences measured in each period were calculated: the perioperative period (period I), the period until implant removal (period II) and the period after implant removal (period III). The Kolmogorov-Smirnov (K-S) test was used to compare the distribution of the angle changes per period with a normal distribution. The K-S test is a one-sample test for goodness-of-fit, like the chi-squared test, but is preferred for small samples because it does not lose information due to combining of categories [22]. Only for angle changes that did not fit a normal distribution a nonparametric test of significance was used (one-sample runs test). Angle changes with a normal distribution were compared using the *t*-test. Angles of patients with and without implant failure were compared using the unpaired *t*-test.

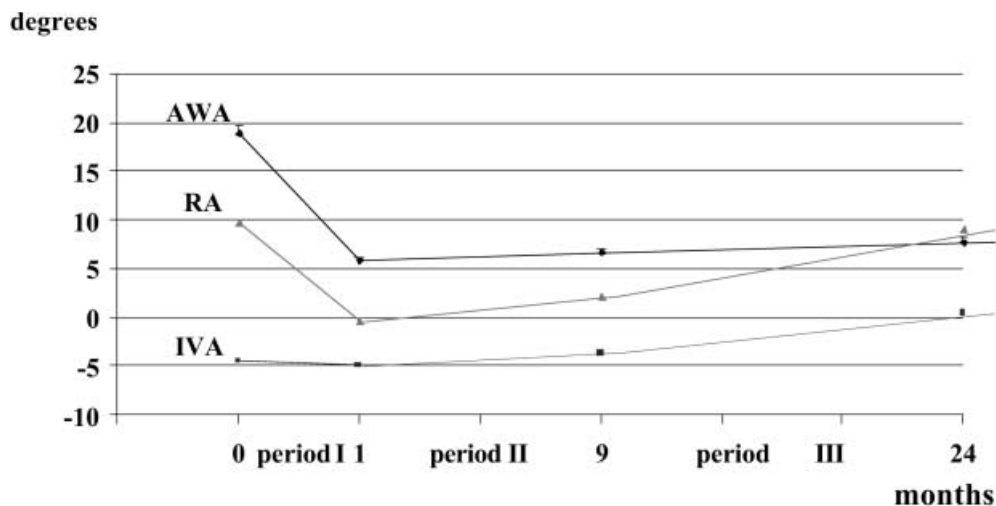
## Results

The mean kyphotic AWA on admission was  $18.0^\circ$ . After the operation this was reduced to  $5.9^\circ$ . At 9 months, before removal of the implants, the mean AWA was  $6.8^\circ$ , and at 24 months  $7.3^\circ$  (Fig. 3, Table 2). The lordotic angle of the IVA on admission was  $4.5^\circ$ , after reduction  $4.9^\circ$ , at 9 months  $3.7^\circ$ , and at 24 months  $-0.4^\circ$ . This means that the lordotic angle at the level of the intervertebral space changed to a neutral angle ( $0.4^\circ$  kyphosis; almost parallel) after implant removal (Fig. 3, Table 2). The mean kyphotic RA on admission was  $9.9^\circ$ . After the operation it was reduced to  $-0.3^\circ$ . At 9 months it was  $2.3^\circ$  and had changed to  $9.2^\circ$  at the end of the follow-up (Fig. 3, Table 2). At that time the RA was similar to the RA on admission.

The K-S test discriminated between parametric (AWA I, IVA I, IVA III, RA I and RA II) and nonparametric distributions of the calculated angle changes (AWA II, AWA III, IVA II and RA III) (Table 3). AWA I, IVA III, RA I and RA II differed significantly from the zero distribution, according to the appropriate test (*t*-test or runs test; Table 3). The changes in AWA obtained during operation (period I) were statistically significant. Later changes were not significant. A separate analysis of changes in the AWA in the type A3 cases with a positive AWA ( $n=101$ ) (mean- $2 \times \text{SD} = 18.0 - 2 \times 7.9 = 2.2^\circ$ ) showed a significant reduction of  $11.5^\circ$  in period I, a small but marginally significant AWA change in period II ( $0.80^\circ$ ,  $P=0.003$ ) and a somewhat larger but still very small and nonsignificant AWA change in period III ( $1.2^\circ$ ,  $P=0.184$ ).

No statistically significant changes in IVA occurred during the course of treatment during periods I and II; the major part of the change in IVA occurred in period III and the difference was significant. The differences of the RAs

**Fig.3** AWA, IVA and RA in time. Positive values indicate kyphosis; negative values indicate lordosis



**Table 2** Different angles in relation to time in 183 patients. Positive AWA and RA indicates kyphosis; positive IVA indicates lordosis

Month	AWA			IVA			RA		
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
0	18.0	7.9	0.88	4.5	4.8	0.37	9.9	11.6	0.59
1	5.9	5.5	0.87	4.9	3.5	0.26	-0.3	11.5	0.41
9	6.8	5.7	0.87	3.7	11.1	0.23	2.3	11.5	0.43
24	7.3	6.2	1.0	-0.4	10.0	0.30	9.2	12.8	0.48

**Table 3** Distribution type of angle changes and runs/t-test results compared to the zero distribution in 183 patients. AWA data are given for 101 type A3 fractures with a positive AWA. The distributions of the measured changes (*PAR* parametric, *NPAR* nonparametric) were tested by Kolmogorov-Smirnov test (*column 4*) in order to perform the right test for comparing the values with the

zero distribution (*column 5*: Student's *t*-test for parametric distributions and the runs test for nonparametric distributions). The total numbers of (complete) pairs of measurements are listed in *column 6* and the number of runs in the runs test in *column 7*. The test values in *column 8* indicate the difference from the zero distribution, and the *P*-values in *column 9* indicate the statistical significance

	Angle change		Distribution (4)	Test (5)	Total cases (6)	Runs (7)	Z/T value (8)	P-value (9)
	Mean	SEM						
AWA I	11.5	0.6	PAR	<i>t</i>	100		19.451	<0.001*
AWA II	-0.8	0.3	NPAR	Runs	97	70	3.070	0.003
AWA III	-1.2	0.9	NPAR	Runs	94	69	1.339	0.184
IVA I	0.90	0.6	PAR	<i>t</i>	165		0.604	0.547
IVA II	-0.064	1.0	NPAR	Runs	171	59	0.247	0.805
IVA III	-4.1	1.1	PAR	<i>t</i>	162		12.579	<0.001*
RA I	10.0	0.7	PAR	<i>t</i>	169		15.040	<0.001*
RA II	-3.0	0.4	PAR	<i>t</i>	172		8.139	<0.001*
RA III	-7.0	0.6	NPAR	Runs	164	19	1.610	0.107

observed in the studied periods were statistically significant before 9 months after surgery, but the changes in the RA after removal of the implants were nonparametric and not significant (Table 3).

In 20 patients (10.9%) one or two pedicle screws were shown to be broken on radiological evaluation 9 months after surgery. Analysis of the changes in the AWA, IVA and RA and when compared with measurements in patients without breakage of screws showed significant

changes in the AWA and RA between primary operation and implant removal, but no changes in the other periods, and no changes in the IVA (Table 4).

## Discussion

Surgery for spinal fractures can be performed with various instrumentation systems including pedicle screws,

**Table 4** Differences in angle changes between 20 patients with implant failure and 156 without implant failure (unpaired *t*-test and significance)

Period	Failures ( <i>n</i> =20)	Controls ( <i>n</i> =156)	Mean difference	Significance ( <i>P</i> -value)
AWA I	12.15	12.01	0.14	0.937
AWA II	-2.15	-0.69	-1.46	0.030*
AWA III	-1.78	-1.17	-0.61	0.735
IVA I	0.67	-0.40	1.07	0.434
IVA II	-1.80	0.85	-2.65	0.144
IVA III	-3.35	-4.26	0.91	0.398
RA I	9.00	10.16	-1.16	0.574
RA II	-8.75	-2.27	-6.48	<0.001*
RA III	-5.18	-7.24	2.06	0.309

hook rods (such as Harrington rods), Luque rods, and anterior instrumentation. Considerable controversy exists regarding the clinical outcome with these different instrumentation systems [4]. Thus Dickman et al. [13], who performed a meta-analysis of surgical treatment alternatives comparing the results from the use of four instrumentation systems, were unable to find convincing evidence as to the best method of treatment of unstable fractures of the thoracolumbar spine. They studied 308 reports published between 1975 and 1994. Of these, 250 were excluded for scientific reasons, and from the remaining 58 they concluded that posterior instrumentation with pedicle screws was the best method with regard to fusion rate, functional outcome and incidence of intraoperative and postoperative complications, including pain and neurological complications. Their study of other aspects concerning the efficacy of different implants and methods did not provide meaningful conclusions, and they stress that no prospectively randomized studies have been reported that comprehensively evaluate the results of different spinal implants for spinal trauma.

In general, retrospective multicentre trials (for example reference 14) are not useful for comparing the results of large series of patients treated with different methods because it is very difficult to allow for differences in surgical technique. Esses et al. [14] had to exclude 25% of their patients because of insufficient follow-up data. Although our study was a retrospective radiological study, all our patients were treated in the same centre by two surgeons, recruited from a group of two (later three) senior staff members and a changing number of junior surgeons. The treatment was performed according to a constant working protocol, that included fixed intervals for radiological evaluation, giving us the opportunity to evaluate the radiological results.

## AWA

We did not find any significant loss in AWA during the first 9 months following surgical treatment (period II) or after removal of implants (period III), although several authors have suggested that the shape of the fractured vertebral body obtained during the operative procedure changes after removal of the implant, with or without spongionoplasty [15]. However, in type A3 fractures with an AWA >2.2° a small but significant loss in AWA was found in the postoperative period [2, 8, 17, 18]. Our favourable results in this respect might have been because of the use of the bilateral transpedicular bone graft procedure. Studies comparing unilateral and bilateral transpedicular cancellous bone grafts have not been performed. The study of Lindsey and Dick [18] showed a small loss in AWA of only 0.5° in 76 patients, and even though all of these patients had a neurological deficit and only 27% of our patients had such a deficit, the results regarding AWA changes are comparable.

## IVA

The IVA at the “affected” segment changed significantly after implant removal. This suggests that the internal fixator and the posterior fusion have a temporary protective effect against collapse of the intervertebral space, but cannot prevent complete disc collapse after implant removal. Independently of weight bearing, this occurred mainly in period III after removal of the implant, as in the study of Lindsey and Dick, in which a 5° loss in the intervertebral space was observed [18].

## RA

Changes in the RA, comparable to the Cobb angle or kyphosis angle in some other studies [6, 15], were observed by us during all phases of the treatment. Posterior instrumentation resulted in the correction of the RA by 10.0°. Loss of RA during the remainder of the follow-up period accounted for 3.0° and 7.0° in the respective periods resulting in a complete return to the preoperative value. This recurrent kyphosis is comparable to the findings of Knop et al. (10.1° in 16–59 months follow-up, mean 40 months) [15], but much more than those reported by Aebi et al. and Olerud et al. (3.6° in 12 months; 4° in 10 months) [2, 20]. In a retrospective study, Crawford and Askin compared two historical groups of patients. They showed that the correction in the RA is greater and maintained better if transpedicular bone grafting of the vertebral body is also performed. This study had a mean follow-up of 9 months. The follow-up was not specified for both groups and therefore it is reasonable to conclude that it was longer for the first historical group (without bone

**Table 5** Changes in RA from fracture reduction until end of follow-up compared to the length of follow-up

Author	<i>n</i>	Months of follow-up (mean)	Loss in RA (after operation to end of follow-up)
Aebi [2]	30	12	3.6°
Crawford [6]	50	(9)	5–8°
Daniaux [8]	44	6–49 (26)	10.4°
Knop [15]	56	16–59 (40)	10.1°
Liljenqvist [17]	26	24–59 (34)	7.2°
Lindsey [18]	76	24	8.5°
Olerud [20]	20	6–17 (10)	4°
Speth [23]	24	18–48 (35)	10–11°
This study	183	24	10.0°

graft) [6]. Certainly the length of follow-up influences the findings (Table 5). A short follow-up shows “good” results, and a long follow-up shows progressive regression to values comparable to the preoperative RA. This explains why early studies [2, 3, 4, 5, 6, 8, 9, 14, 17] showed good results from posterior instrumentation. Only recently has this recurrent kyphosis, despite transpedicular fixation, been shown by Speth et al. [23] and Knop et al. [15], but in relatively small numbers of patients and/or with a short follow-up.

Nonsignificant changes in RA occurred in period III ( $P=0.107$ ), although the differences were rather large, they can partially be explained by the nonparametric distribution and therefore the obligatory nonparametric runs test, the relatively large standard deviation, and large standard error of the mean. Possibly, this might have been caused by poor reproducibility of the measurements: the RA may have been influenced by postural factors at the level of the second disc. The IVA at the level of the caudal end plate at  $t=0$  could have been larger as a result of ventral distraction in the preoperative supine position after trauma. The other measurements were done on sitting or standing radiographs. Regression towards the “normal” IVA value of the second disc at 24 months would influence the RA and could be an additional explanation for the relatively large regression of the RA (Fig. 3, Table 2).

Collapse of both discs could be due to degeneration as a response to both trauma and immobilization. Fusing only two of the three instrumented vertebrae has – at least theoretically – the advantage of regaining mobility at the second segment as early as possible after implant removal. This does not mean that the second disc will not be influenced by the procedure. Accelerated degeneration of

the facet joints adjacent to a lumbar fusion has been described by Lee [16]. Implant removal at 9 months could interfere with the posterior spondylodesis, accelerating the return to the preoperative RA values. It is likely that avoiding posterior fusion at the second segment and early implant removal do not prevent degeneration of the second disc.

Subgroups, for example type A3 fractures with a positive AWA, were only evaluated separately in this study with respect to changes in the AWA. The effect of the posterior, one-level spondylodesis in relation to the segmental range of motion will be presented in a separate report. Canal clearance, posterior wall height restoration and related topics will be the subjects of a third report.

Breakage of pedicle screws led to statistically significant changes in the AWA and RA in period II but surprisingly not to differences in the changes in the IVA (Table 4). Therefore we cannot conclude that the (intact) internal fixator only temporarily prevents disc collapse; breakage of pedicle screws is not reflected at disc level. We were not able to determine the exact moments of screw breakage; patients did not report any symptoms and the radiological evidence of implant failure could only be found at the scheduled check-ups, before implant removal. Screw breakage mainly occurred before 1990 when we advised our patients to wear a corset for only 6 months and we removed the implants at 12 months. This suggests material fatigue and a breakage tendency of 5 mm screws. From 1990 we advised patients to wear the brace until implant removal at 9 months to protect the screws against breakage. However, this function of bracing has been questioned by Rohlmann et al., who showed that braces do not prevent stress in internal fixators [21].

## Conclusions

1. The reduced vertebral body does not collapse after removal of the implants at 9 months.
2. Internal fixation and posterior spondylodesis cannot prevent collapse of the affected intervertebral space occurring after implant removal, and this collapse contributes significantly to the loss of the RA.
3. The RA at the end of 2 years was shown to be almost similar to the preoperative value.
4. Implant failure occurring between primary operation and implant removal had a significant influence on the AWA and RA before implant removal, but did not influence the IVA.

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